# How to Perform Your Land Cover/Biology Investigation

The goals of the Land Cover/Biology Investigation are threefold:

1. to take detailed measurements at selected sites within the entire GLOBE Study Site. These measurements are used by scientists to study vegetation growth and change and to verify maps made from remotely sensed data.

2. to make observations at many sub-areas within the entire study site. These observations are used by scientists, and can be used by you, to validate land cover maps generated from remotely sensed data.

3. to create a land cover map of your entire study area. This map will be used in learning more about your surroundings by making observations and measurements at selected sample locations. Upon competing this investigation, you will know a great deal about the environment surrounding your school and will be able to monitor change as it happens.

## Study Sites for the Investigation

The Land Cover/Biology Investigation requires two different kinds of study sites. The first is called the GLOBE Study Site and is the 15 km x 15 km area, with your school near the center, for which satellite imagery is provided to you by GLOBE. By performing the protocols and learning activities associated with this investigation, you and your students will become intimately familiar with this part of our global environment. Together, you will create a land cover map of the entire area, make observations about many sub-areas, and take detailed measurements in some of these areas.

Within this GLOBE Study Site, it is important that you select appropriate ground sites (called Land Cover Sample Sites) for detailed measurements and observations. See Figure LAND-P-1. From an instructional standpoint, the goal of these Land Cover Sample Sites is to give your students a feel
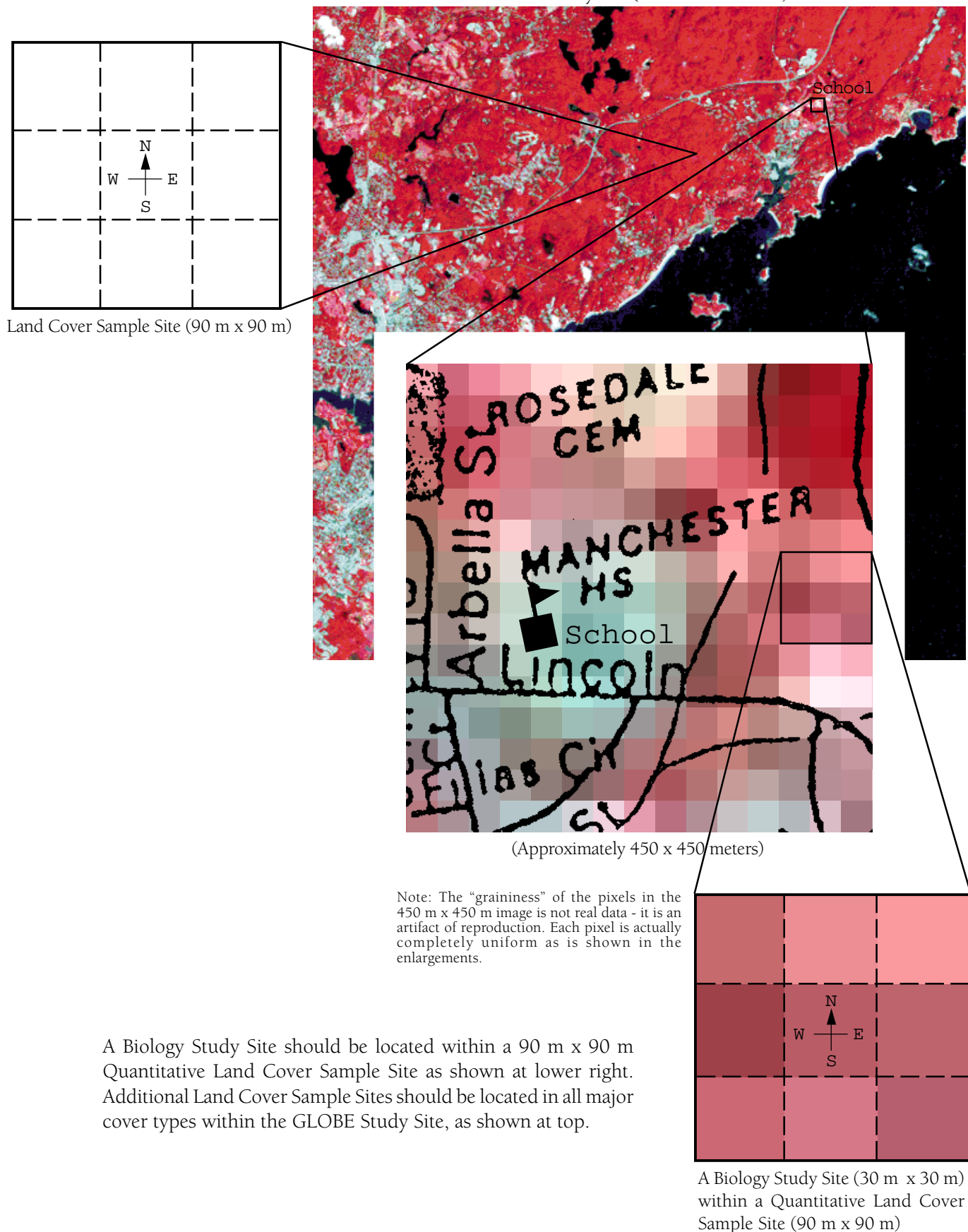
for the physical dimensions of *pixels* (picture elements) in the Landsat satellite Thematic Mapper images as well as providing a suitable and convenient site for class measurement activities within the GLOBE Study Site. For scientific purposes, a series of ground observations described later in this section need to be made in selected sample sites which are both representative of major types of land cover within your 15 km x 15 km study area, and large enough that they can be reliably located in satellite imagery.

Land Cover Sample Sites are areas of homogeneous land cover at least 90 m x 90 m in size. If the homogeneous area is larger than 90 m x 90 m, then the sample site is located toward the center of the area. See Figure LAND-P-3. An area 90 m x 90 m is necessary in order to accurately locate it on the ground and on the satellite imagery. This area is equivalent to 9 Landsat Thematic Mapper (TM) satellite pixels (a square of 3 pixels by 3 pixels). See the *Remote Sensing* section of the *Implementation Guide*.

There are two kinds of Land Cover Sample Sites - Qualitative and Quantitative. The latitude, longitude, and elevation of all Land Cover Sample Sites must be determined using a GPS (Global Positioning System) receiver, the land cover must be classified using the Modified UNESCO Classification (MUC) system, and the land cover must be documented in photographs taken from the middle of the site. The data for Qualitative Land Cover Sample Sites are easier to collect and require only these observations. Quantitative Land Cover Sample Sites require detailed measurements of the vegetation at the site and are only possible for certain land cover types. Qualitative and Quantitative Land Cover Sample Sites are visited only one time. However, within at least one Quantitative Land Cover Sample Site, each school should establish a permanent Biology Study Site. This site is used for obtaining long-term, periodic data related to vegetation growth. The Biology Study Site should be located in the center of a

*Figure LAND-P-1: Land Cover Sites, Beverly, MA, USA as an example*

GLOBE Study Site (15 x 15 kilometers)



Land Cover Sample Site (90 m x 90 m)

(Approximately 450 x 450 meters)

Note: The "graininess" of the pixels in the 450 m x 450 m image is not real data - it is an artifact of reproduction. Each pixel is actually completely uniform as is shown in the enlargements.

A Biology Study Site should be located within a 90 m x 90 m Quantitative Land Cover Sample Site as shown at lower right. Additional Land Cover Sample Sites should be located in all major cover types within the GLOBE Study Site, as shown at top.

A Biology Study Site (30 m x 30 m) within a Quantitative Land Cover Sample Site (90 m x 90 m)
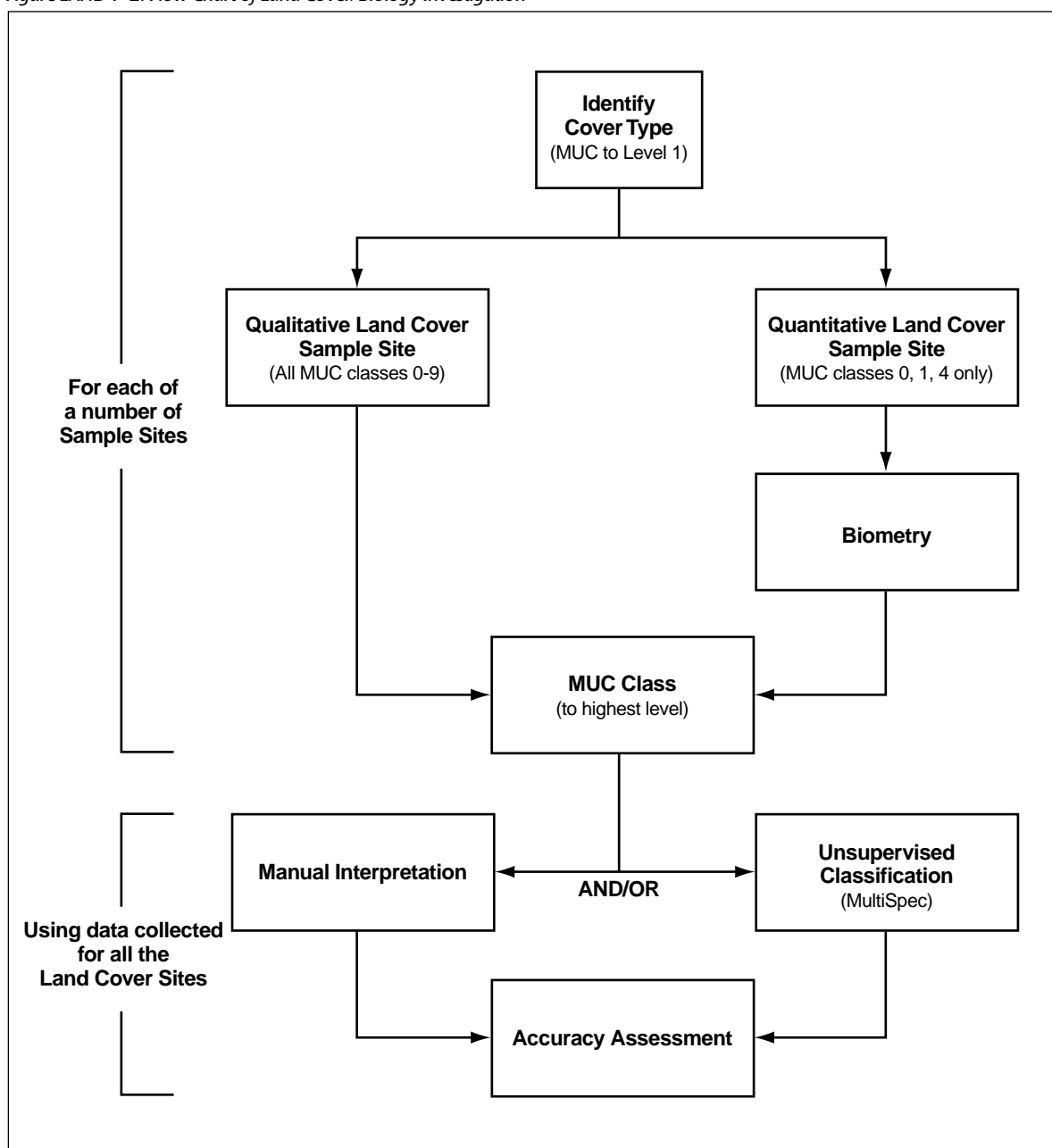
Quantitative Land Cover Sample Site. Only homogeneous areas of Forest, Woodland, or Herbaceous vegetation can be Quantitative Land Cover Sample Sites. You will learn more about this in the next section and in the *MUC System Protocol*.

The following flow diagram (Figure LAND-P-2) presents the steps to take to complete the Land Cover/Biology Investigation. The first step is to identify the general land cover type. All the other steps in this diagram correspond to protocols.

## Identify the General Land Cover Type

The characterization of GLOBE Land Cover Sample Sites can only proceed within the context of a specific land cover classification system. The system used for GLOBE is the Modified UNESCO Classification system (MUC). This classification system is a tool for putting every possible land cover type on Earth into a unique land cover class. Each MUC class is a distinct type of land cover, with a name and an identification number, or MUC code.

*Figure LAND-P-2: Flow Chart of Land Cover/Biology Investigation*



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### About the MUC System

The GLOBE program uses MUC, an ecological classification system which follows international standards and ecological terminology for the identification of specific land cover classes. By using a standard international classification system, all the GLOBE data may be compiled into a single regional or global land cover data set. Thus ground data may be gathered and used to validate remotely sensed data following the same scientific protocols worldwide. This classification system enables GLOBE participants to accurately describe the land cover at any one point on Earth using the identical criteria as all other GLOBE participants.

There are two components of the MUC system. Part one is the outline of the classification system, containing the hierarchical list of labels for every class. Part two is the glossary, with rules and definitions. Before classifying any land cover type, it is crucial to *always* check the definition of the particular land cover class you believe is appropriate. Even if you think you know what a forest is, you should check the definition to confirm that your site is, in fact, a forest and not a woodland.

MUC has a hierarchical, or tree, structure, with ten level 1 classes. These classes are very general and easily identified. You must select one unique MUC class to identify a land cover type at each MUC level, beginning at level 1. Within each level

1 class there are two to six more detailed level 2 classes. Level 2 classes are still quite general and easily distinguished. Levels 3 and 4 are more specific communities or vegetative associations. The hierarchical structure of the MUC system simplifies the classification process. At each level your choices are restricted to only those classes which fall within the single class you have selected at the previous level. Thus while the whole MUC classification system has over 150 classes, at each step your choice is typically among only three to five land cover types.

In order to conduct the Land Cover/Biology Investigation, it is necessary first to identify the level 1 MUC class for each Land Cover Sample Site Each level 1 class is general and can be identified by visually estimating the percentage of the ground covered by the land cover present at the sample site. Table LAND-P-1 shows the 10 level 1 MUC classes. All MUC level 1 classes are determined by the percentage of the total sample area covered by the dominant land cover type.

### Identifying MUC Level 1 Class

1. Select an area of homogeneous land cover as your Land Cover Sample Site.
2. Visually estimate the percent of the ground covered by the dominant land cover.
3. Review MUC level 1 class definitions to be sure students understand them.
4. Proceed with the steps of How to Classify Land Cover Sample Sites to MUC level 1 given in the *MUC System Protocol*.

*Table LAND-P-1: Level 1 MUC Land Cover Classes*

| MUC Code | MUC Level 1 Classes | Coverage Required |
|---|---|---|
| 0. | Forest | >40% Trees, 5 meters tall, crowns interlocking |
| 1. | Woodland | >40% Trees, 5 meters tall, crowns not interlocking |
| 2. | Shrubland | >40% Shrubs, 0.5 to 5 meters tall |
| 3. | Dwarf Shrubland | >40% Shrubs, under 0.5 meters tall |
| 4. | Herbaceous Vegetation | >60% herbaceous plants, grasses, and broadleafed plants (forbs) |
| 5. | Barren | <40% vegetative cover |
| 6. | Wetland | >40% vegetative cover, includes marshes, swamps, bogs |
| 7. | Open Water | >60% open water |
| 8. | Cultivated Land | >60% non-native cultivated species |
| 9. | Urban | >40% urban land cover (buildings, paved surfaces) |

Once you have established the level 1 MUC class of a Land Cover Sample Site, you are ready to proceed with one of the Land Cover Sample Site Protocols. If a Land Cover Sample Site is a forest or woodland or is covered by herbaceous vegetation (i.e. MUC level 1 land cover classes 0, 1, or 4), students may take the biometry measurements described in the Quantitative Land Cover Sample Site and *Biometry Protocols*. In other areas, GLOBE does not currently have protocols for biometry or other detailed quantitative assessments of the land cover. For these sites, students should take the measurements in the *Qualitative Land Cover Sample Site Protocol*. In some cases, you may decide to use a particular site as a qualitative sample site and not take biometry measurements even though the level 1 MUC class of the site would allow it to be quantitative sample site.

## Establishing Different Types of Sites

In general, GLOBE schools only establish one of their Quantitative Land Cover Sample Sites as a permanent Biology Study Site, but establishing more sites is permissible. Over time, the goal is to establish one or more Land Cover Sample Sites in each of the major types of land cover identified within your 15 km x 15 km Globe Study Site. Start with the most common types of cover, and continue to add sample sites until you have located them in as many of the cover types as possible. When your school has the GPS instrument, measure and record the center point longitude, latitude, and elevation of all Land Cover Sample Sites you have identified up to that time.
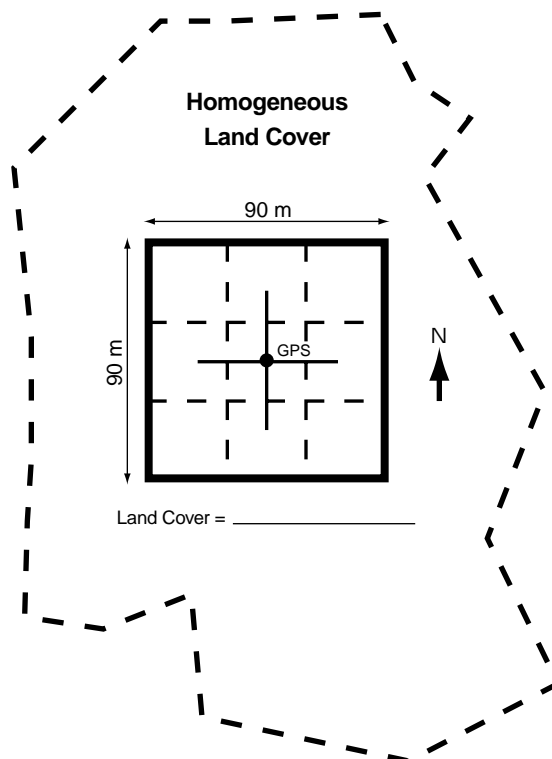
Additional Land Cover Sample Sites are important for verifying the accuracy of land cover maps, which is a key scientific objective of GLOBE. It is recognized, however, that it will take time, perhaps several successive years, to accumulate a set of sample sites representative of each important type of cover within your Globe Study Site. You may want to assign a cover type to each of several classes, so that no two classes are working in the same type of cover and so as much data as possible are collected.

## Qualitative and Quantitative Land Cover Sample Sites and Their Use in Land Cover Mapping

There are two types of land cover data collected in the GLOBE protocols — *qualitative* and *quantitative*. There are also two purposes for which you will use these land cover data: (1) help in labeling your land cover map (training), and (2) validating (or assessing the accuracy) of your classified land cover map (validation). Both are critical components to any mapping project using remotely sensed data and are analogous to the ways in which scientists and others will use your data.

Both training and validation data are collected for 90 m x 90 m sites, usually within your 15 km x 15 km GLOBE Study Site. These sites are called *Land Cover Sample Sites, and* must be within areas of homogeneous land cover. See Figure LAND-P-3. For this investigation, homogeneous land cover means that the entire site is representative of one of the specific land cover classes defined in the *MUC System Protocol*.

*Figure LAND-P-3: Homogeneous Land Cover Site*



Homogeneous
Land Cover

90 m

90 m

GPS

N

Land Cover = _____

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*Table LAND-P-2: The Uses of Qualitative and Quantitative Data in Land Cover Mapping*

Data Type

| | | Qualitative Land Cover Sample Sites | Quantitative Land Cover Sample Sites |
|---|---|---|---|
| Data Purpose | Training Data | Obtain the lay of the land during map development; assign land cover classes quickly | Gain a thorough understanding of the appearance of land cover types on ground and image |
| | Validation Data | More easily obtain enough land cover sites for statistically valid map accuracy assessment | Best for map accuracy assessment; detailed information about forest, woodland and herbaceous vegetation sites<br>Helps students and scientists understand appearance of cover types on both the ground and satellite images |

The following definitions should be helpful in understanding the difference between the types of data collected and the data collection methods.

Training Data: Land cover data collected at Land Cover Sample Sites to help identify or label unknown clusters on the unsupervised classification of the TM image and/or to help in the manual interpretation of the TM image. These data can be collected using qualitative or quantitative data collection methods. Training data should *never* be used to assess the accuracy of the map because they have been used in the training process and you can not use the same data to train as well as validate your results.

Validation Data: Land cover data collected at Land Cover Sample Sites to assess the accuracy of the classified map created using manual interpretation or unsupervised classification of your local TM scene. These data can be collected using qualitative or quantitative data collection methods (quantitative is preferred whenever possible). Collect as many samples as possible for each land cover type present on the map because many samples are needed in the accuracy assessment process. These data should be used *only* for accuracy assessment.

Qualitative Data: In GLOBE, qualitative observation of land cover at a Sample Site requires only 3 components: (1) determining the latitude, longitude, and elevation of the site using GPS, (2) defining the MUC class using student observations of the site, and (3) taking photos in the four *cardinal* directions (i.e. north, south, east and west). This abbreviated set of land cover data can be used for *either* training or validation sites. Qualitative data are useful, especially when initially learning what land cover classes exist in your area and how to correlate what the land cover types look like on the TM image with what the same areas look like on the ground.

Quantitative Data: Quantitative land cover measurements are only possible for land cover classes for which GLOBE currently has Biometry Protocols (i.e., naturally occurring forest or woodland or herbaceous vegetation). In addition to the observations made for Qualitative Land Cover Sample Sites, at Quantitative Land Cover Sample Sites students take the measurements specified in the biometry protocol. These data are collected primarily for validation of maps generated from satellite imagery. The additional biometry measurements provide students and scientists with a more thorough understanding of forest, woodland, and herbaceous vegetation sites.

### The Mapping and Accuracy Assessment Process

Figure LAND-L-4 illustrates the logical steps in producing a land cover map and assessing its accuracy. You are encouraged to begin collecting data on Land Cover Sample Sites even before you begin this mapping process. Student observations of individual sites are valuable because scientists can use them in their own land cover maps.

*Figure LAND-P-4: Diagram of Accuracy Assessment Process*

**Step 1: Manual Interpretation or Unsupervised Clustering**

The TM image is divided into areas of similar land cover type manually or using MultiSpec.

**Step 2: Assign MUC Classes to Areas or Clusters**

For each area created by the manual interpretation or cluster created using MultiSpec, assign a MUC code using students' knowledge of the area and data collected from qualitative or quantitative training sample sites.

**Step 3: Collect Validation Data**

Once the land cover map is made, collect validation data at additional Land Cover Sample Sites to assess the accuracy of the classified map.

Over time, observe and measure as many validation sample sites as possible for each of the land cover types in your area.

(T) **Training Sample**

[V] **Validation Sample**

*Figure LAND-P-4: Diagram of Accuracy Assessment Process (continued)*

**Step 4: Assess Map Accuracy**

**Validation Data**

| | 0222 | 0221 | 1121 | 811 | **Row Total** |
|---|---|---|---|---|---|
| **0222** | | 1 | | | 1 |
| **0221** | | 1 | | | 1 |
| **1121** | | | 1 | | 1 |
| **821** | | | | 1 | 1 |
| **Column Total** | 0 | 2 | 1 | 1 | 4 |

**Map Classification** (vertical axis label)

Using the difference/error matrix, compare the map classes to the validation sample classes determined from your observations and calculate the overall accuracy.

**MUC Classes**

0222 = Mainly deciduous forest with evergreen needle leaved trees

0221 = Mainly deciduous forest with evergreen broad leaved trees

1121 = Mainly evergreen woodland with rounded crowns and needled leaves

811 = Pasture

**Overall Accuracy = (3/4) * 100 = 75%**
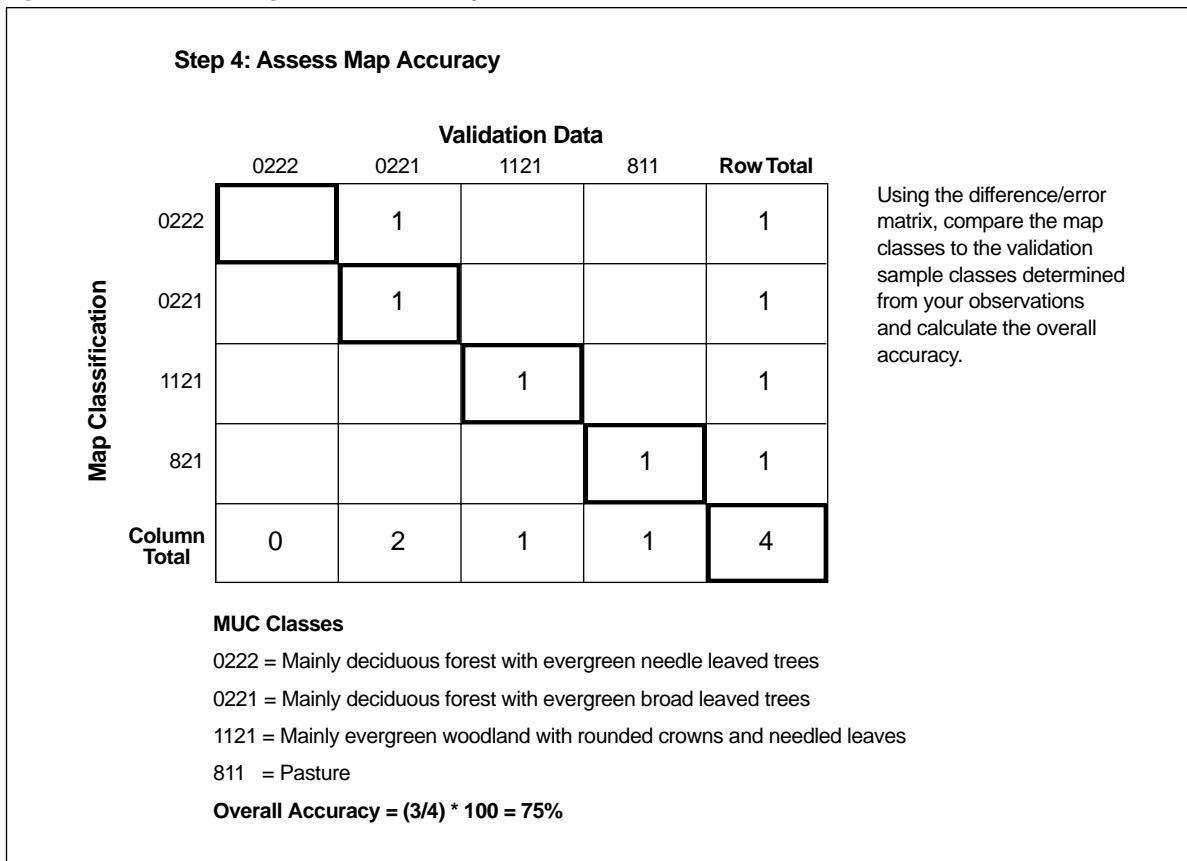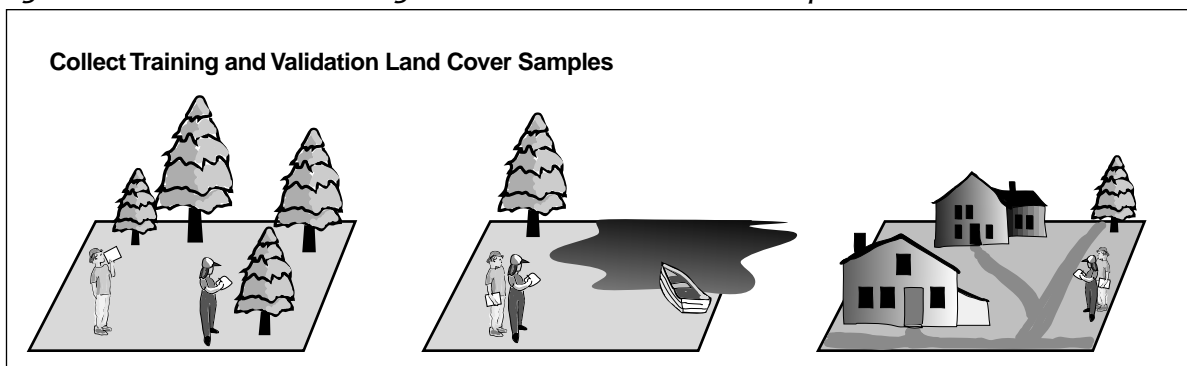
*Figure LAND-P-5: Collect training and Validation Land Cover Samples*

**Collect Training and Validation Land Cover Samples**

## Special Considerations

Several time management, educational, and logistics issues should be considered in deciding how to present and undertake the various Land Cover/Biology protocols.

- Quantitative land cover information is far more useful and offers students a more complete view of the land cover assessment process.
- Measurement of a Quantitative Land Cover Sample Site involves careful biometry measurements, and students generally benefit from practicing these measurements before going to their study and sample sites.
- Virtually all GLOBE Study Sites contain developed areas of land cover, and in these areas only Qualitative Land Cover Sample Sites are possible.
- If a GPS receiver and a camera are available, observation of a Qualitative Land Cover Sample Site can be accomplished quickly.
- Data from multiple Land Cover Sample Sites are necessary in order to perform a manual interpretation of the entire GLOBE Study Site or to label the clusters that

result from an unsupervised classification using MultiSpec. Even more validation sites must be collected to assess the accuracy of the land cover map generated either manually or using MultiSpec.
- Schools should collect as many sample sites as possible for each land cover type present on their land cover maps because many samples are needed in the accuracy assessment process; sites collected in different years and by different classes or even neighboring schools all can be used.
- The validation data must be independent of the data collected for training; it is not appropriate to use the same data for both training and validation because this will bias the results. Therefore, whatever data were collected and used for training must be set aside and only other samples used for validation.

Be sure to note the difference between naturally vegetated sites and cultivated sites. The Qualitative Land Cover Sample Sites can be collected for all land cover types. At present, the Quantitative Land Cover Sample Sites can only be collected for MUC classes 0, 1, and 4.

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